PROCEDURES TO CHOOSE OPTIMAL ENGINEERING SOLUTIONS FOR DAIRY FARMS

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Abstract. The paper describes two methods to choose the most feasible engineering and space-planning solutions when reconstructing old dairy farms and building new ones.

Keywords: dairy farm, technology, matrix, process engineering, estimation of parameters.

Introduction

The design of any enterprise, an agricultural one included, consists of several parts, with the principal one being a technological mode. As a rule a farm houses the animals of different sex and age groups, and they are on different phases of their biological cycle. Each group has its special requirements to housing and handling technologies. The task of the process designer is to form the technologies, which would, on the one hand, comply with the animal welfare requirements, and on the other hand, provide adequate working conditions for animal breeders aimed to facilitate operations, to increase labor productivity, to lower self costs of animal products, and to prevent environmental pollution with animal waste.

Materials and methods

To make the above task easier the set of possible combinations of relevant technological elements is arranged in an array, where each element is assigned a code and placed in a special array cell [1]. Such a matrix is very convenient for computer-aided analysis and synthesis of technologies. It makes the forming of a farm-specific technology substantially easier and quicker. Based on this matrix Directory of Recommended Technologies has been compiled for different farm departments – lactation, pre-calving and calving, and also for all departments for replacement and fattening young animals (followers).

To facilitate the procedure of choosing the most feasible options, an engineering work station has been designed, which helps the process designer to form the technology in an interactive mode. The system of computer-aided designing includes a set of basic and supplemental reference databases, dialog work items and a package of algorithms for initial data conversion and interaction. The dialog mode allows combining substantial processing power of a computer with the expertise of a qualified livestock expert. The offered variants may be estimated by various criteria, such as cost, labor, material, energy, ecology, and quality indicators.

However such a workstation requires availability of complete and reliable information on all the task components. In most cases such comprehensive information is not in place. Therefore, along with the above workstation and the matrix array of techniques of cattle housing and handling, the process engineering is recommended to be applied. This integrating method considers a big number of factors and dependences, which do not yet have quantitative characteristics.

The first and important step in the process designing is to estimate process-dependent parameters of a farm. The methods and algorithms have been developed to identify these parameters for different number of cows' open days (period between two calvings) under both specified fed cow population and specified capacity of the lactation department. To estimate the key parameter of a dairy farm – the so-called biological conveyer rate (i.e. average number of cattle head entering each department per day) – under the specified fed cow population we have to know the average number of open days [2]. When designing new farms to calculate the biological conveyer rate, the capacity of lactation department and adopted work cycle of its sections (animal stay plus cleaning time) are needed besides the above initial data.

The biological conveyer rate, the number and capacity of sections and their work cycle, the number of feeding days, waste output, water consumption and other important indicators are calculated for each farm department. The offered calculation procedure both estimates the optimal parameters of a farm and helps to manage the farm in the future, using the data on animal weight and productivity dynamics, feed and other resources consumption, and comparing actual and estimated indices. This method provides the rhythmical travel of technological groups of animals from one department to another depending upon their transition from one biological phase to another. The calculation results of the technological parameters may be presented in graphs and activity diagrams. If these activity diagrams have dates and months, they may be used as schedule plans for all farm departments. They may also show the dates of zoo-technical and veterinary measures to be taken in accordance with the travel of technological groups of animals. Such schedule plans give a complete per day picture of animal housing and travel, substantially facilitate planning and control, contribute to more strict procedure discipline and better farm management.

To make the process engineering of facilities for loose cubical cattle housing easier, technological modules of various type and size have been designed [3]. As it turned out there are only seven basic modules in this respect, which differ in mutual arrangement of cubicles, feeding and defecation areas (Figure 1).

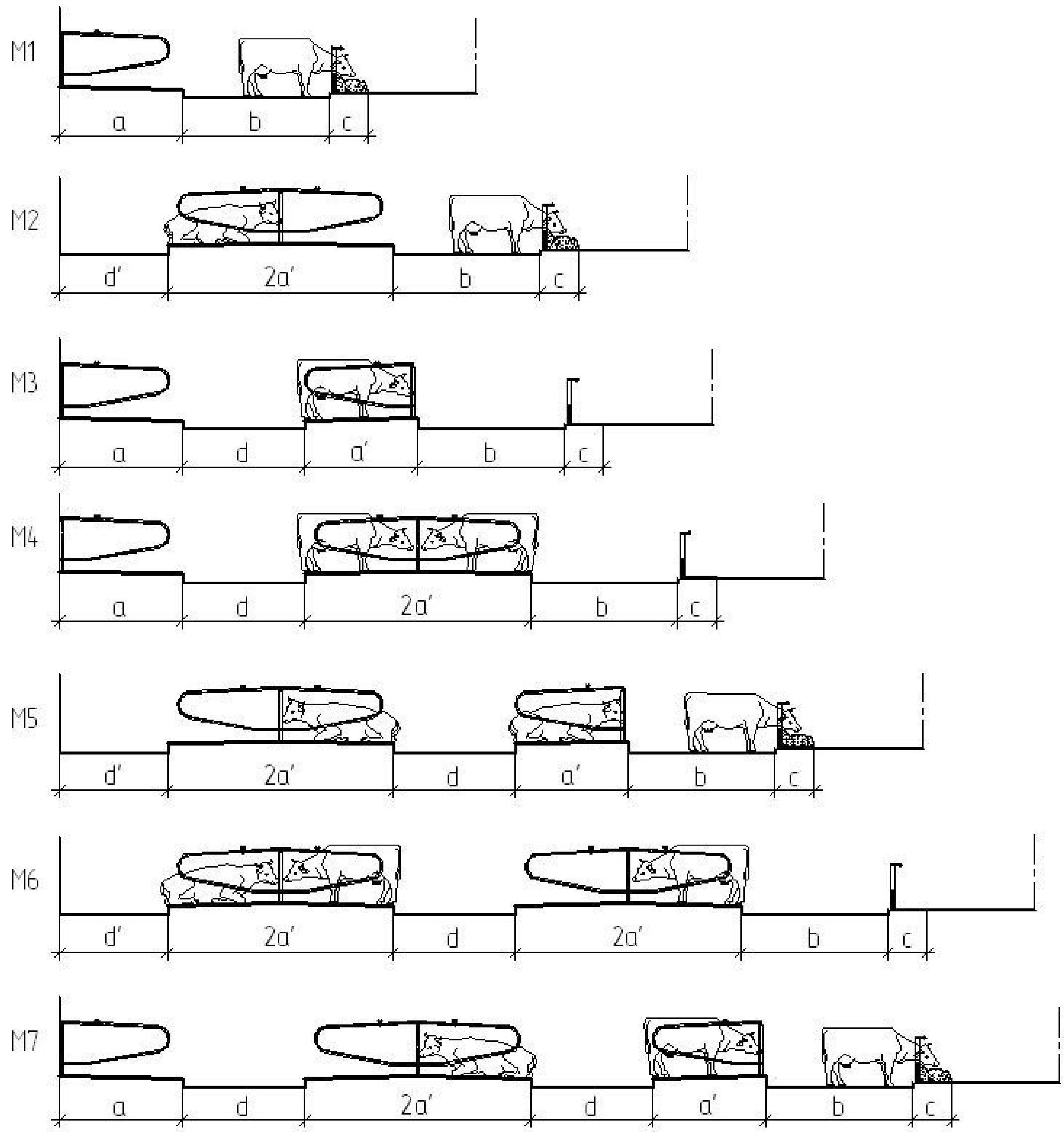

Fig.1. **Technological modules for loose cubicle housing of cattle:** a – the length of wall-adjacent cubicle; a’ – the length of the open cubicle; b – the width of feed-and-manure removal passage; c – the width of the feeding area; d – the width of a manure removal passage between the adjacent rows of cubicles; d' – the width of a manure removal passage for one row of cubicles

Depending upon the width and structural layout of a building, one, two and more modules or their combinations may be inserted. The calculations show that when two adjacent technological modules are used, there are 45 layout options, with each having its strong and week points. The module effectiveness indicators are its specific width and the area per animal unit, which are taken into account when choosing the proper engineering solution.

The institute has also developed technological patterns for reconstruction of standard barns [4]. For example, we offer 10 different reconstruction options for 21 meters wide farm buildings. On the basis of the recommended patterns the engineering designs for reconstruction of dairy farms in Leningrad Oblast and other regions of Russia have been developed. As an upgrading result, the outdated farms are turned into advanced enterprises with high quality and competitive production, in which case the number of workers, who handle the herd, are two or three times smaller, but their working conditions are much better, and the milk quality and its selling price are higher.

The construction of new animal houses, first of all, barns, is of current interest. In this connection we have developed engineering designs for modular barns [5], which may be used on the farms of various sizes with the capacity from 400 to 2000-plus cows. The peculiar feature of the module layout is that eight sections instead of regular four may be arranged in the barn. This allows making the gap in the waiting time for expected calving of the cows in the same technological group much shorter, i.e. the group becomes more uniform. In this case the conditions for animal feeding and handling are better, they comply with animal productivity and lactation phase. And also the negative impact of cow ranking relations is smaller. All this contributes to more efficient feed consumption and higher milk yields. Moreover, the smaller groups require substantially smaller area of the holding room in the milking parlor, smaller labour inputs and less water for its cleaning, and what is most important, less waiting time for milking. The risk of environment pollution with the manure-bearing waste water also decreases [6]. The technical and technological solutions for dairy farms chosen by help of the above methods have been field-tested and have proved to be highly efficient.

Discussion

Computer-aided analysis of the array of possible technologies for animal housing and attendance substantially simplifies and accelerates the procedure of choosing the technological elements best suited for a particular farm. But we cannot disregard the fact that relations between the technological elements have not been formalized yet, these elements do not have qualitative characteristics and are to a great extent dependent on the structural layout and dimensions of animal houses. All this considerably complicates the choice of engineering options by available mathematical methods.

Conclusions

Efficient methods to choose engineering solutions when reconstructing the existing dairy farms or when constructing new ones are (1) analysis of the matrix array of the possible technologies of cattle housing and attendance in an interactive mode participating customer's representative and (2) the process engineering, which includes estimation of process-dependent parameters of a farm, outlining of cattle housing patterns and cattle motion paths as well as the sequence of operations in each department.

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